

Annual Report to the National Oceanic and Atmospheric Administration's
Climate Program Office, Sectoral Applications Research Program (SARP)

**Portfolio-based Approaches to Managing Climate Uncertainty in Urban Water Planning
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Principal Investigators: Gregory W. Characklis (lead), University of North Carolina at Chapel Hill; Patrick M. Reed, Pennsylvania State University; Ronald C. Griffin, Texas A&M University

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Project Summary:

Significant uncertainties are associated with the degree to which climate change will alter regional rainfall and streamflow patterns, and these represent serious challenges to urban water supply planners, as almost all water system designs are based on the assumption that these patterns are “stationary”. Increasing evidence that climate change is impacting the hydrologic cycle has resulted in the assertion that “stationarity is dead”, raising doubts about the usefulness of the historical record as the primary design parameter for urban water supply systems. Thus, water utilities are struggling to develop new planning paradigms that provide greater flexibility in the face of climatic uncertainty which, combined with pressures of rising demand, presents them with serious challenges. Adding further urgency to this issue are projections of near-term (present to 2025) expenditures on water-related infrastructure, which are expected to be in the hundreds of billions of dollars. Given that many of these projects will have 50+ year lifespans, a period over which climate change is predicted to have significant but uncertain effects, the importance of innovation in developing water management strategies becomes increasingly clear.

This project involves the development of tools and guidelines to support a modern paradigm for water supply planning under conditions of climatic uncertainty. It includes the coordination of a diverse “portfolio” of water-related “assets” including: supply infrastructure (e.g., reservoirs); conservation technologies (e.g., water reuse); transfers among different users (e.g., utilities, industries), and; demand management measures (e.g., pricing, usage restrictions). Diversification has long been a strategy for dealing with uncertainty in other industrial sectors, and while there is tacit acknowledgement that more diversified supply strategies could benefit urban water utilities, previous attempts at implementation have largely been unstructured and *ad hoc*. This work is focused on providing generalized and transferable approaches to coordinating a diverse portfolio of supply and demand management alternatives, and this knowledge has the potential to substantially improve urban water utilities’ ability to cope with climatic uncertainty. It also includes considerations of a portfolio’s impact on a utility’s financial stability, an important factor as diversification may give rise to more volatile cost and revenue streams. The interdisciplinary research team (including an engineer, economist and systems specialist) is working in partnership with the four primary water utilities in the rapidly growing Research Triangle region of North Carolina. This work builds on existing projects and relationships with these utilities, each of which have been integrally involved in the formulation of the project’s direction and objectives.

Project Objectives:

This project advances the urban water supply portfolio approach as a means of mitigating the risks of climatic uncertainty. Our primary tasks are (i) identifying the objectives and metrics that urban water utilities will use to evaluate portfolio designs; (ii) developing decision-support tools that allow for a clear analysis of tradeoffs between multiple objectives within various portfolios (e.g., reliability, cost, cost variability, resilience, etc.), and; (iii) examining alternative

institutional structures (e.g., regulatory, financial) for their ability to aid the utilities in designing portfolios better able to cope with severe planning uncertainties.

Progress Report:

Over the nine month reporting period, we have made substantial progress in a number of areas. We have acquired and scrubbed datasets from all four of the regional utilities (Figure 1) and now have the information required to fully characterize the regional hydrologic systems, each utility's demand profile and each utility's financial status. All nine regional reservoirs are now included in the model. We have historic data on inflows for each reservoir and have used these records as a basis for developing synthetic flow records using a new approach (modified Fractional Gaussian Noise, or mFGN, see Kirsch and Characklis, in press). This approach allows us to generate synthetic records at a weekly time scale that retain seasonal variability in serial correlation similar to that in the historic record, even as it reflects the impacts of variations in standard moments of the historic flow distribution arising from climate change. This also allows us the freedom to evaluate as many realizations on the system as suits our needs.

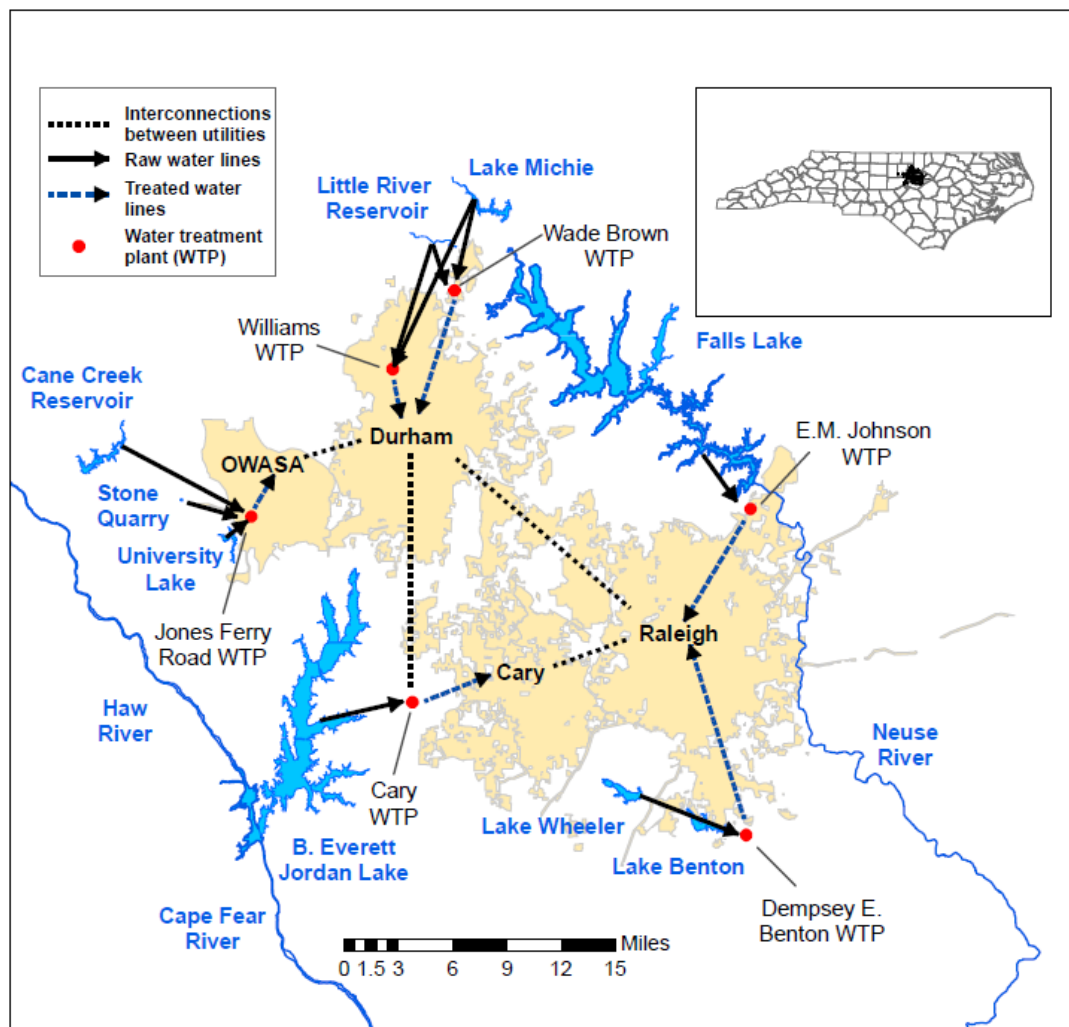


Figure 1 The Research Triangle Region of North Carolina, including relevant hydrologic and water-related infrastructure

This brings up another issue, which is that of the computational burden associated with the analyses. Concerns over runtimes will always be an issue, and given that some of the previously developed model components were built using the MATLAB platform (which is relatively slow), there were some worries over efficiency, so the entire modeling framework has now been converted to C++, which should alleviate some of these concerns.

The model has also been interfaced with the advanced computational and visualization tools being developed at Penn State, and preliminary results evaluating portfolios in terms of Costs, Cost Variability, Conservation activities (and related revenue losses) and Reliability, among other metrics have been generated (for an example, see Figure 2). These analyses provide an initial assessment of the range of potential portfolio configurations and, more importantly, an improved understanding of the tradeoffs associated with multiple objectives. Connections between the PIs groups continues to be strong with two face-to-face meetings in the past nine months, as well as several conference calls (with visual aids). In addition, a graduate student from UNC has spent time in residence at Penn State in order to become more familiar with the computational and visualization tools being developed by Dr. Reed's group. Similarly, there are currently plans for a Penn State student to pay an extended visit to UNC in order to familiarize himself with the primary model formulation, as well as to gain an improved understanding of regional system as a whole.

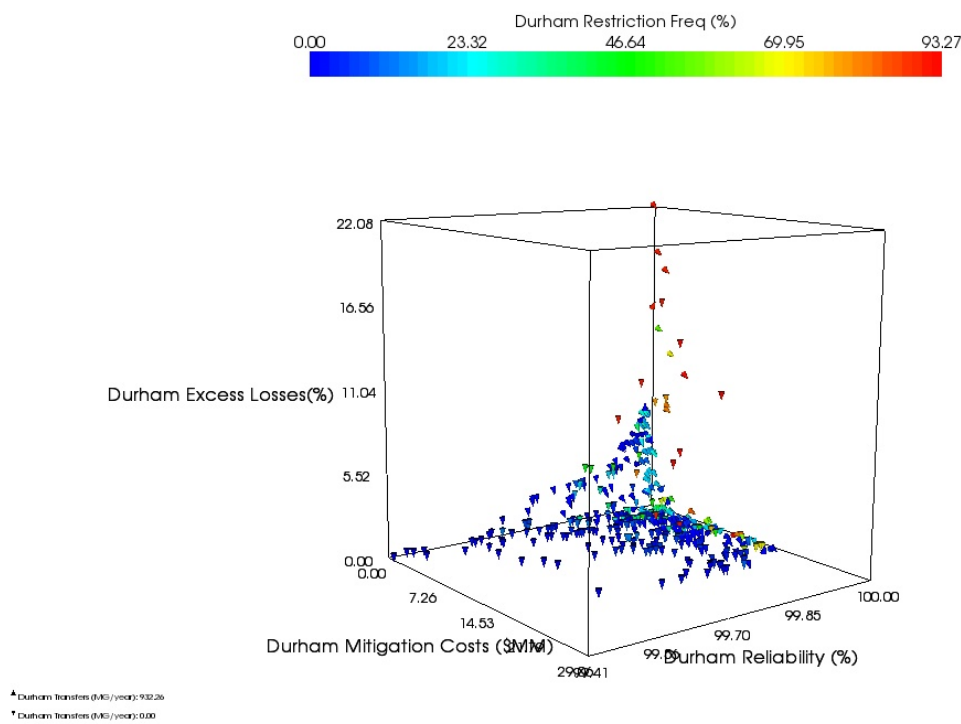


Figure 2 The performance of a number of candidate portfolios in terms of reliability, conservation restriction frequency, conservation losses and mitigation costs (City of Durham)

With respect to the objective of maximizing financial stability, an objective measured by fluctuations in utility revenues and costs brought about by the implementation of conservation measures and the purchase of water from other utilities, respectively (Figure 3), we have also been evaluating a number of different approaches. These include the use of drought

surcharges, contingency funds and third-party insurance contracts as a means of mitigating the effects of revenue variability arising from conservation (Figure 4). These results are helping us understand the degree of financial volatility faced by the utilities, something that concerns them, and will allow us to formulate portfolios that give due consideration to this criterion.

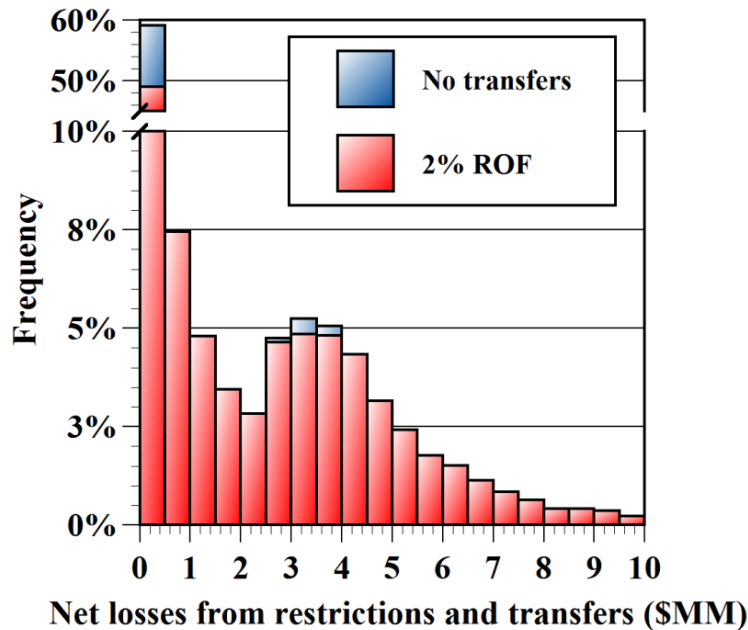


Figure 3 Net utility losses as a result of (i) conservation measures (reduced revenues) without transfers and (ii) the combination of conservation measures and transfers (governed by a specific type of contract, e.g., “2% ROF”)

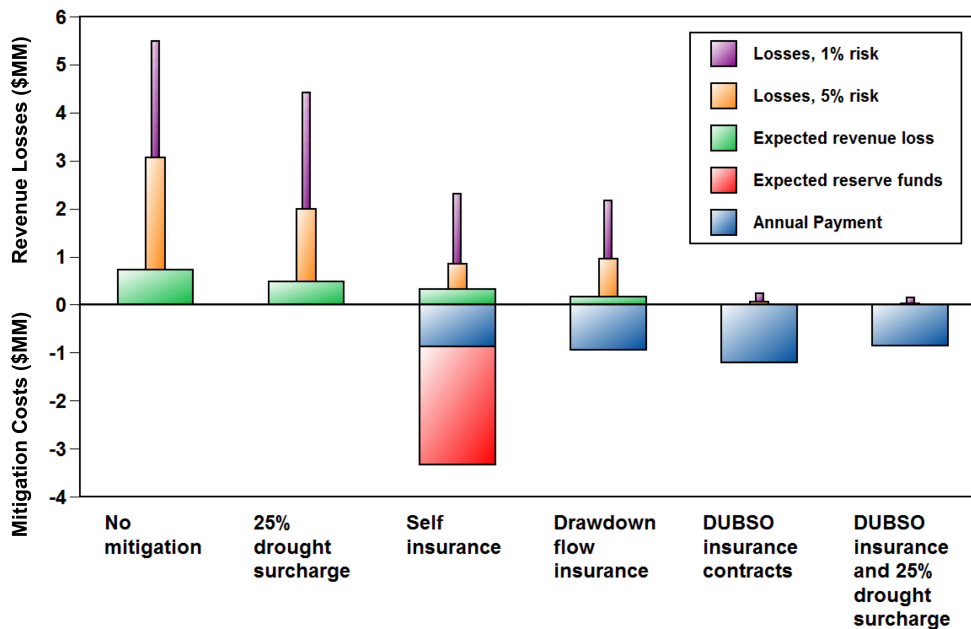


Figure 4 Several alternatives for managing revenue variability arising from drought-related conservation measures and their relative performance

Finally, we have maintained close contact with our utility partners over the course of the last nine months, with two meetings (January 2012 and June 2012) at which we presented preliminary results and discussed various aspects of portfolio formulation. All four utilities continue to be actively engaged and to provide us with data and insights which are valuable in the conduct of the project.

Future Activities:

We have a working model of the entire Research Triangle system, including the hydrologic, demand and financial data/relationships necessary to explore a wide range of management options, and have used this to generate preliminary results. We are now in a position to focus on exploring the full range of alternative portfolios in much greater detail, with an emphasis on refining our multi-objective problem, evaluating/expanding the range of management, infrastructure and institutional alternatives to be considered, and assessing the adaptiveness and resilience of the entire regional system to a range of potential future climate scenarios. Furthermore, we will be actively engaged with the utilities as we seek to refine our use of visualization and decision support tools that will allow them to become even more involved in understanding, navigating and selecting the portfolio configurations that best meet their objectives in the face of climatic uncertainty.